MULTIMEDIA UNIVERSITY

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FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EMG4066 – ANTENNA AND PROPAGATION

(TE)

05 MARCH 2019
2.30 p.m. – 4.30 p.m.
(2 Hours)

INSTRUCTION TO STUDENT

1.This question paper consists of 6 pages including cover page with 4 questions only.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the answer booklet provided.

Question 1

(a) Describe the mechanism of microstrip antenna and state three advantages by using this antenna.

[7 marks]

(b) You are designing a five-turn helical antenna operating at 400MHz in normal mode operation. This antenna needs to work in circular polarization. The spacing between turns is $\lambda/50$. Determine the antenna properties as follows:
i. Circumference of the helix
ii. Length of a single turn
iii. Overall length of the entire helix
iv. Pitch angle

[3+3+3+4 marks]

(c) The directivity of a pyramidal horn antenna with aperture width a and height b is $D = 6.4\frac{ab}{\lambda^2}$. Find its aperture efficiency. If the power density around the antenna is 1 W/m^2, find the received power.

[5 marks]

Question 2

(a) In sky wave propagation, derive the range of communication in terms of virtual height, critical frequency and Maximum Usable Frequency (MUF).

[10 Marks]

(b) Calculate the critical frequency and maximum usable frequency (MUF) of an ionospeheric layer with electron concentration $10^{10}/m^3$ and the virtual height is 250km.

[7 marks]

(c) Calculate the radio horizon for a 150m transmitting antenna and receiving antenna of 6m. Calculate the required height increase for the receiving antenna if a 20% increase in radio horizon is required. Assume the link is operated in a standard atmospheric condition with K=4/3. Take the radius of earth to be 6400km.

[8 marks]

Continued...

Question 3

(a) Consider a dipole antenna of length l and its far field pattern is given by

$$f(\theta)=\frac{\cos\left(\frac{\beta l}{2}\cos\theta\right)-\cos\left(\frac{\beta l}{2}\right)}{\sin\theta}$$

Show that for $l \ll \lambda$ where λ is the wavelength, the radiation pattern of dipole reduces to that of short wire antenna.

[7 marks]

(b) If an antenna of a transmitter with gain G_t radiates power of P_t watt, prove that the field strength at any given distance R from the antenna is given by

$$E_R=\frac{\sqrt{30P_tG_t}}{R}\ volts/meter$$

[11 marks]

(c) Calculate the length of a short dipole antenna excited with a 0.2 A current at 2.4GHz. The magnitude of the tangential electric field is 0.3 V/m along the antenna broadside at a distance of 200 λ , where λ is the wavelength at 2.4GHz.

[7 marks]

Question 4

(a) Consider a communications link which is operated at 1GHz, and the transmitting and receiving antennas have a gain of 20 dBi and 15 dBi, respectively. The antennas are separated by 1 km. Find the maximum received power under impedance-matched conditions when the transmit power P_t=150W, if (i) the antennas are polarization matched, and (ii) antenna polarization loss factor reduces to half.

[6 marks]

(b) Write down the expression for power density at a distance d, in terms of transmit power and gain of the transmitting antenna in free space. Show that the Friis transmission equation at distance d in free space is given by

$$P_{rx}=P_{tx}G_{tx}G_{rx}\left(\frac{\lambda}{4\pi d}\right)^2$$

where P_{tx} and P_{rx} are the input and output power from the transmitter and receiver respectively. G_{tx} and G_{rx} are the gain of the transmitting antenna and receiving antennas respectively, and λ is the free space wavelength.

[8 marks]

Continued...

(c) A 7.5km free space radio link operating at 318.3MHz is to provide minimum power of 1μw at the receiver. The antennas connected to the transmitter and receiver are 14dBi and 6dBi respectively.

i) Determine the minimum transmit power. Assume no other losses or mismatch in the link.

[7 marks]

ii) If the link is increased to 15km with the same transmit power, would it be any impact on the received power. If yes, explain how this affects the received power? If not, explain why.

[4 marks]

End of paper.

APPENDIX

Constants and Formulae (All symbols have their usual meanings)

Constants and Formulae:

Boltzmann's constant	$k = 1.38 \times 10^{-23} J/k$
Plank's constant	$h = 6.6266 \times 10^{-34} J.s$
Light velocity in free space	$c = 3 \times 10^{8} m/s$
Electron Charge	$e = 1.6 \times 10^{-19} C$
Permeability of free space	$\mu_o = 4\pi \times 10^{-7} H/m$
Permittivity of free space	$\varepsilon_o = \frac{10^{-9}}{36\pi} F/m$

Friss Transmission & Propagation

$$P_r = P_t \frac{G_t G_r}{d^4}(h_t h_r)^2 \qquad P_{rad} = 40\pi^2 \left[\frac{L}{\lambda}\right]^2 I_m^2$$

$$P_D = \frac{P_{tx} G_{tx}}{4\pi R_{tx}^2}$$

$$h_{inc} = \frac{D_1 D_2}{2KR} \qquad r = \sqrt{\frac{D_1 D_2 \lambda}{D_1 + D_2}}$$

$$P_R = \frac{|E|^2}{120\pi} A_e \qquad E_R = 2\frac{E_0}{d}\sin\left(\frac{2\pi}{\lambda} \bullet \frac{h_t h_r}{d}\right)$$

$$E = \frac{\sqrt{30 P_t \bullet G_t}}{d} \qquad MUF = f_{cr} Sec\theta_i \qquad n = \sqrt{\varepsilon_r} = \frac{\sin\theta_i}{\sin\theta_r} = \sqrt{1 - \frac{81N}{f^2}}$$

$$d = 2R\left[(\pi/2 - \beta) - \sin^{-1}\left(\frac{R}{R+h}\cos\beta\right)\right] \qquad d_{\max.single\text{-}hop} = 2R\cos^{-1}\left(\frac{R}{R+h_{\max}}\right)$$

$$h_{eff\ obs} = h_{inc} + h_{obs} + 1st.FZ \qquad D = 2h_r\sqrt{\left(\frac{f_{MUF}}{f_c}\right)^2 - 1}$$

$$d = \sqrt{2KRh_{tx}} + \sqrt{2KRh_{rx}}$$

Antenna

$$P_{ave} = \frac{1}{2}\left[\mathrm{Re}(E \times H^*)\right] = \frac{E^2}{2\eta}\hat{a}_r$$

$$R = 2D^2 / \lambda$$

$$D = \frac{4\pi U_{\max}}{P_{rad}}$$

$$P_{rad} = \oint_S P_{ave}\, dS = \oint_S P_{ave} r^2 \sin\theta \, d\theta \, d\varphi$$
$$= \int_S U(\theta,\varphi)\sin\theta \, d\theta \, d\varphi$$
$$= \int_{\varphi=0}^{2\pi}\int_{\theta=0}^{\pi} U(\theta,\varphi)\, d\Omega$$

$$W = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}}\sqrt{2/(\varepsilon_r+1)}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+12d/W}}$$

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L$$

$$U_{ave} = \frac{P_{rad}}{4\pi}$$

$$\frac{\Delta L}{h} = 0.412\frac{\left(\varepsilon_{reff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)}$$

$$P_r = \frac{P_t}{4\pi r^2}$$

$$D(\theta,\phi) = \frac{U(\theta,\phi)}{\frac{1}{4\pi}\iint U(\theta,\phi)d\Omega}$$

$$A_e = \frac{D\lambda^2}{4\pi}$$

$$P_r = \frac{1}{2}\left[\frac{|V_{oc}|}{2R_{rad}}\right]^2 \quad R_{rad} = \frac{|V_{oc}|^2}{8R_{rad}}$$

$$R_{rad} = 80\pi^2\left[\frac{L}{\lambda}\right]^2$$

$$AF = a_1 e^{j\alpha_1} + a_2 e^{j(\beta d\cos\theta+\alpha_2)} + a_3 e^{j(2\beta d\cos\theta+\alpha_3)} + \ldots + a_N e^{j((N-1)\beta d\cos\theta+\alpha_N)}$$

$$|AF| = \frac{\sin(N\psi/2)}{\sin(\psi/2)}, \quad \psi = \beta d\cos\theta + \alpha$$